Contest University Finland

”Understanding HF propagation”

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(translated and revised English presentation)

HF conditions and contests in a nutshell

1. ***Learn the basics!*** *The sun is a prerequisite for all contest QSOs. The sun's activity creates the HF propagation conditions and also propagation disturbances.*
2. ***Make propagation predictions!*** *Understanding HF propagation conditions and predictions are important for your contest strategy to maximize the points. Using prediction software is increasingly easier; there are web-based services & smartphone apps.*
3. ***Study grayline maps!*** *Propagation predictions on the lower bands are of less use, we will need to study the grayline maps.*
4. ***Watch the weather!*** *The importance of watching the real-time space weather and propagation has increased during the contests and in preparing for them.*

What is propagation?

- *In this presentation, we only talk about propagation on HF (3-30 MHz).*
- *A successful QSO depends on the ionosphere and its state. The state of the ionosphere varies by hour, by day, by month.*
- *We often say there are undisturbed (quiet) and disturbed propagation (or ionospheric) conditions.*

- ***REMEMBER**: knowing the sunspot number or A/K indices will tell you nothing about concrete HF propagation conditions!*

What is propagation?

- HF propagation has band-specific features (frequency)
- HF propagation has a geographical direction; there is a TX and RX (location, circuit)
- HF propagation in a certain direction is bound to the time of day
- Other factors are also involved, such as:
  - Transmitting power
  - Antennas
  - Transmission mode
  - Noise
  - Short/Long path

1. Making an HF prediction is easy!

- *Our basic understanding of propagation comes from **VOACAP** (Voice of America Coverage Analysis Program) – online.voacap.com*
- ***Point-to-point**, P2P, predictions and **coverage area** predictions (ie. a matrix of P2P predictions)*
- ***VOACAP predictions are the basis** for our understanding of the propagation characteristics over one month*
- *You do not have study any math or physics: VOACAP has everything that is necessary.*
- ***Input values** have to be as accurate as possible: TX/RX, month, power, antennas and TX mode*
- ***Use VOACAP Online**: the prediction is a graphic image that shows the probability of getting QSOs as a function of time and frequency*
- ***There is more under the hood**: take a peek at [http://...]**/prediction.txt***
- *VOACAP also available as an Android smartphone app: **DroidProp**!*

Case: A search for an optimal contest QTH

- Head for lower latitudes
- Stay away from areas of high atmospheric noise
- Use the 6,000-KM rule
- Maximize QSO rates, points and multipliers
- Run VOACAP REL maps for candidate QTHs from 40M to 10M
- Use grayline maps and calculate sunset/sunrise times for 160-80M

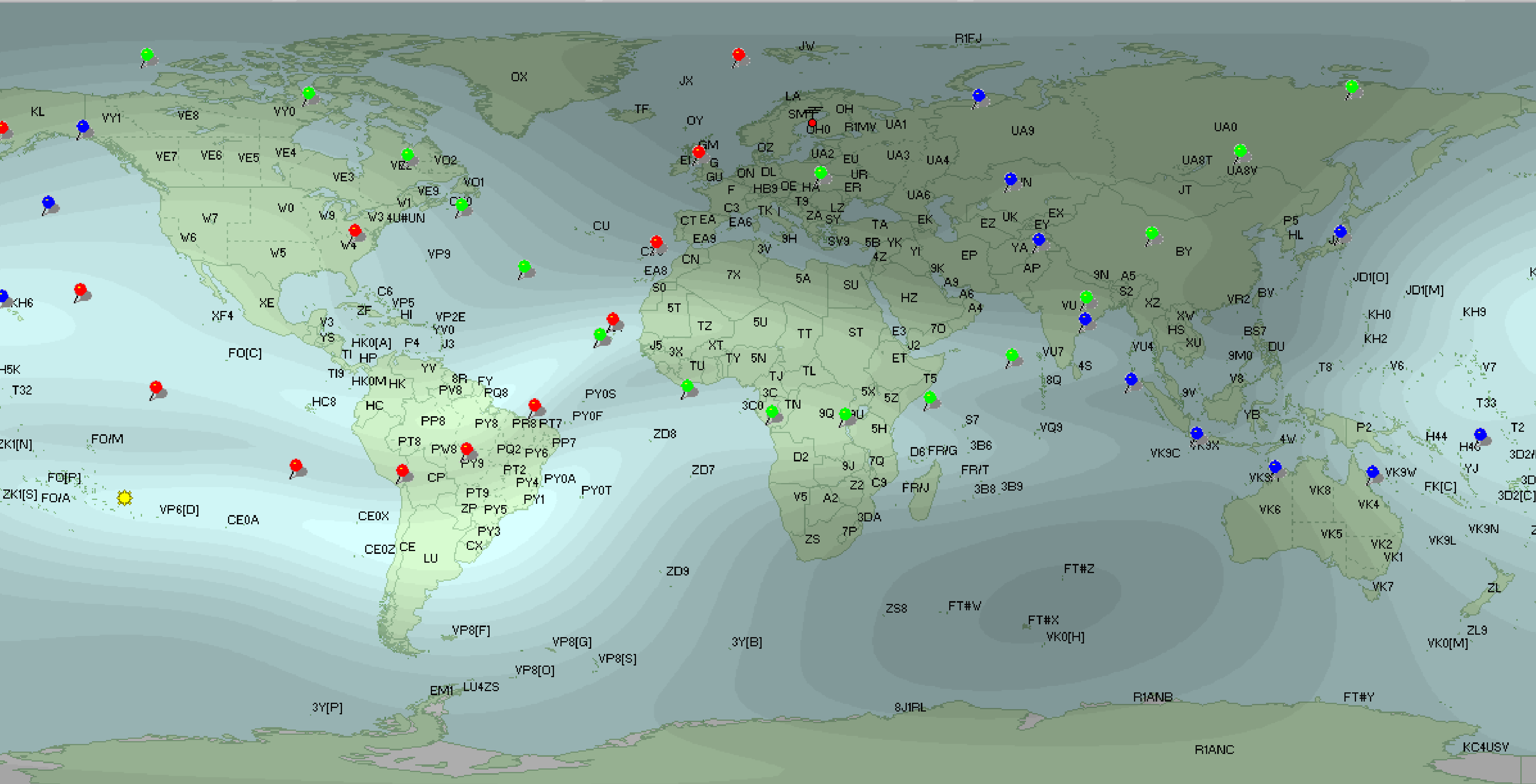
The 6,000-KM Rule

- *Use the 1F2 and 2F2 propagation modes, which means a maximum path distance of about 6,000 KM*
- *See if there is a location on the earth that gets to the most hams within the 6,000-KM limit. That location gives you the highest probability of getting QSOs on the lower bands.*
- *On 160M and 80M there may be more than 2 F2 hops at 6,000 KM*
- *On the upper bands, paths of over 6,000 KM also work well!*

The 6,000-KM Rule

Centers: Red= W4; Green= HA; Blue= JA

Drawn on a foF2 map (the lighter the area, the stronger the ionosphere)

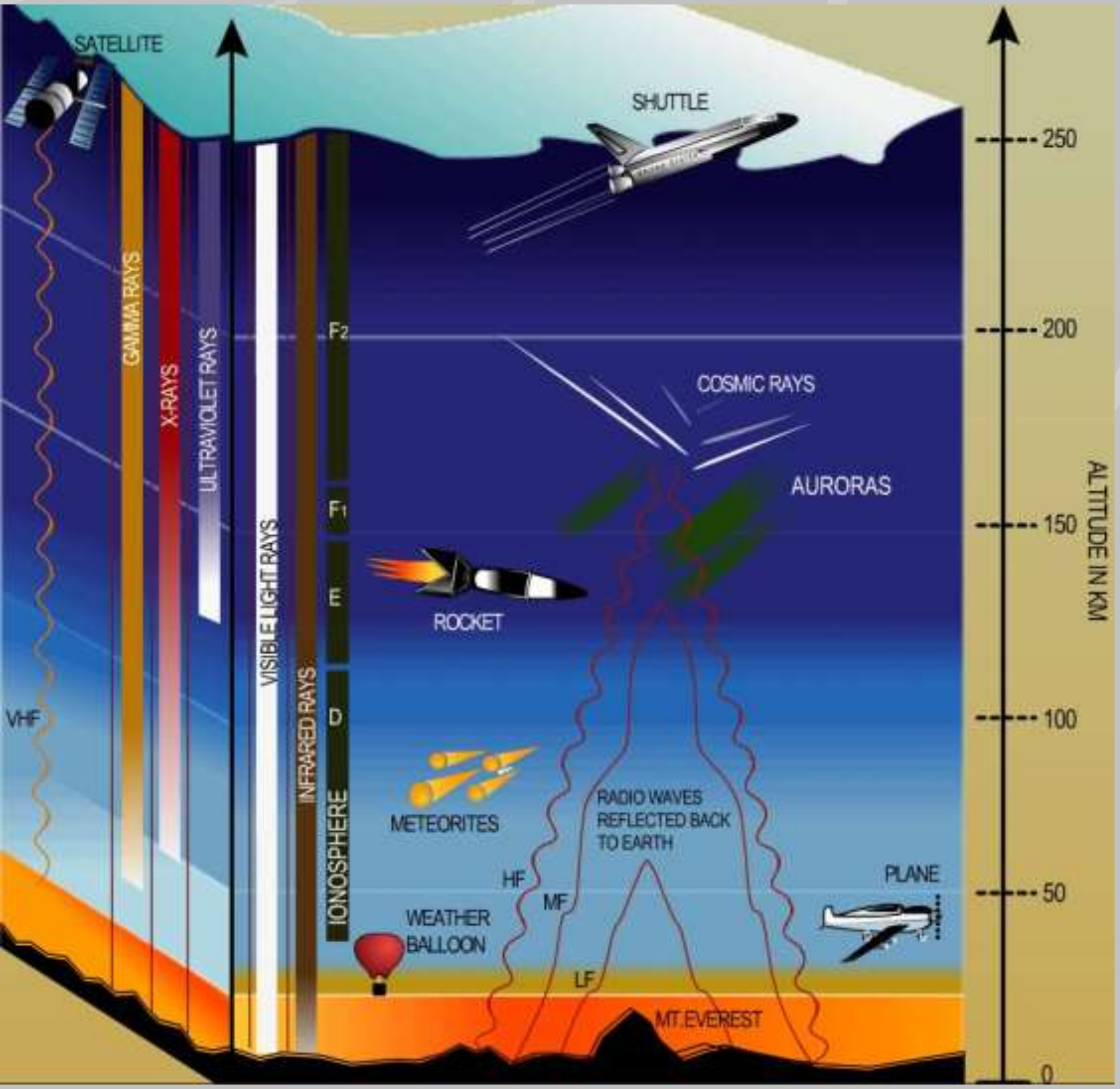


2. Ionosphere

- *The ionosphere is a layer in the atmosphere where gases can be photoionized as a result of external radiation*
- *Photoionization = a process in which a photon strips an electron from a neutral atom*
- *On Earth, most of ionization results from the sun's x-ray and ultraviolet (UV) radiation. The radiation is at its greatest during the daylight hours.*
- *There are many layers in the ionosphere because the gases absorb the sun's radiation at different wavelengths.*
- *For signal propagation, more important than the positive ions are electrons and their number.* ***Only these free, negative electrons can reflect radio waves.***
- *Photoionization vs. Recombination!*

D Layer (60-100 km): *ionization due to "hard" x-ray radiation (0.1-1 nm, 1-10 Ångström)*
E Layer (100-150 km): *ionization mostly due to "soft" x-ray radiation (1-10 nm, 10-100 Ångström)*
F Layer (150-500 km): *UV radiation (10-100 nm, 100-1000 Ångström)*

The layers of the ionosphere



D Layer: *60-100 km*

E Layer: *100-150 km*

F Layer: *150-500 km, divides into two, F1 (170 km) and F2 (250 km).*

3. Regular ionospheric variations

- ***By time of day*** *(e.g. disappearance of D and E layers after sunset)*
- ***By season*** *(e.g. the variation of the height of the F2 layer in the winter and summer)*
- ***By geographical location*** *(e.g. ionization strongest at the equatorial areas, high critical frequencies of the F2 layer)*
- ***By the sun's cyclical nature*** *(sunspot minimum and maximum, which affect the long-term nature of the ionosphere, and the 27-day rotation cycle of the sun)*

4. The sunspots

- *Galileo Galilei made the first scientific observations in ca. 1610.*
- *The sunspots are **strong centers of the magnetic field** on the surface of the sun, typically even thousands of times stronger than the Earth's magnetic field.*
- ***A sunspot appears** because, at that specific point, the magnetic field is so strong that it prevents the movement of the sun's fluid material. The hot stuff cannot come to the surface, making the surface cooler and darker.*
- ***A sunspot disappears** when the magnetic field weakens or disperses, and the hot plasma again starts to come to the surface from the core of the sun.*
- ***The size of the sunspots**: a few thousand kilometers in diameter; the largest, tens of thousands of kilometers.*
- ***Occurrence**: often in pairs or in small groups.*

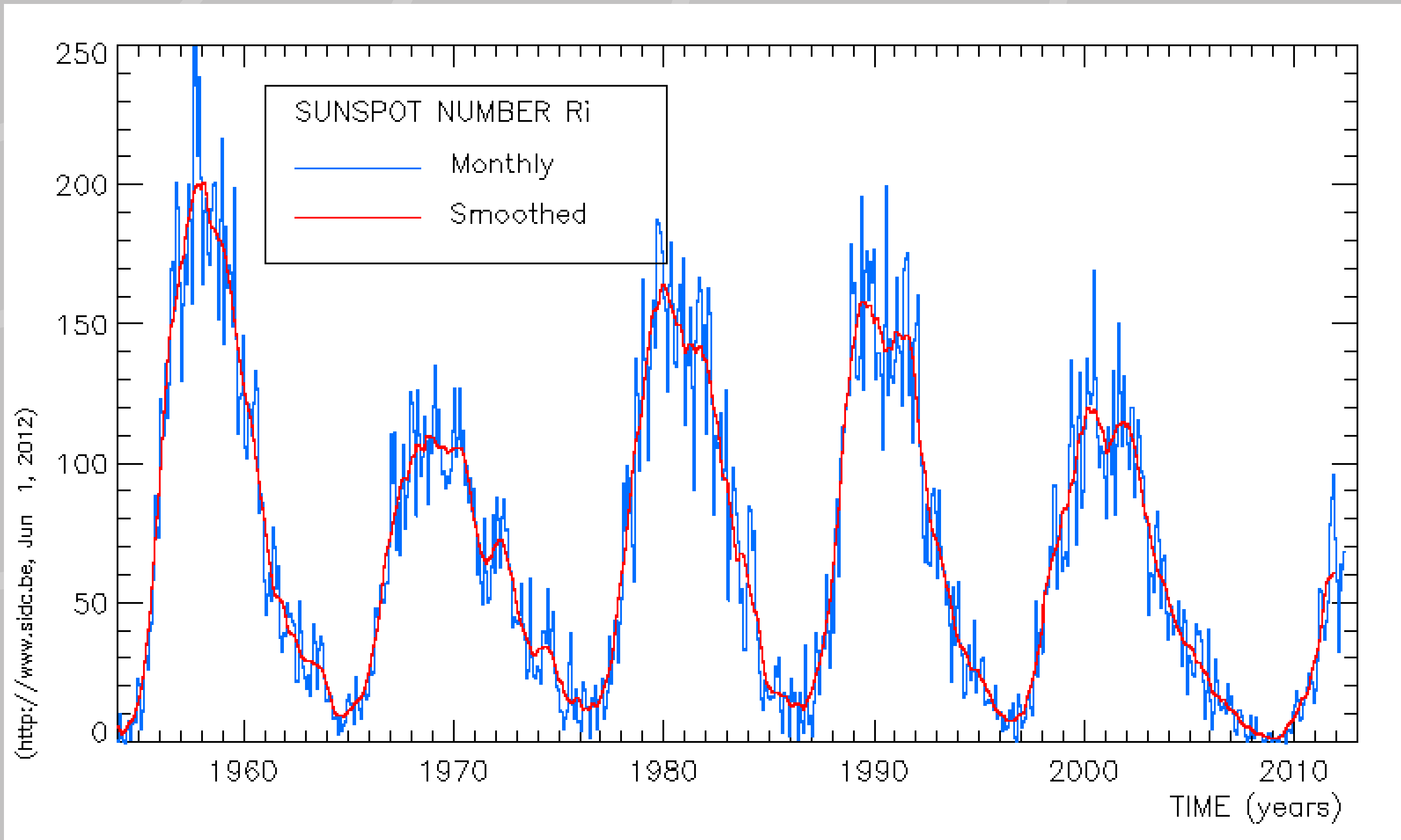
The cyclic variation of sunspots

- *The number of sunspots varies in cycles of about 11 years.*
- *There are 2 phases in a solar cycle: a rise phase and a fall phase.*
- *The rise phase typically lasts just under 5 years, and the fall phase just over 6 years.*
- *The Solar Cycle 1 started in 1755, and now we are in Solar Cycle 24.*

The sunspot number

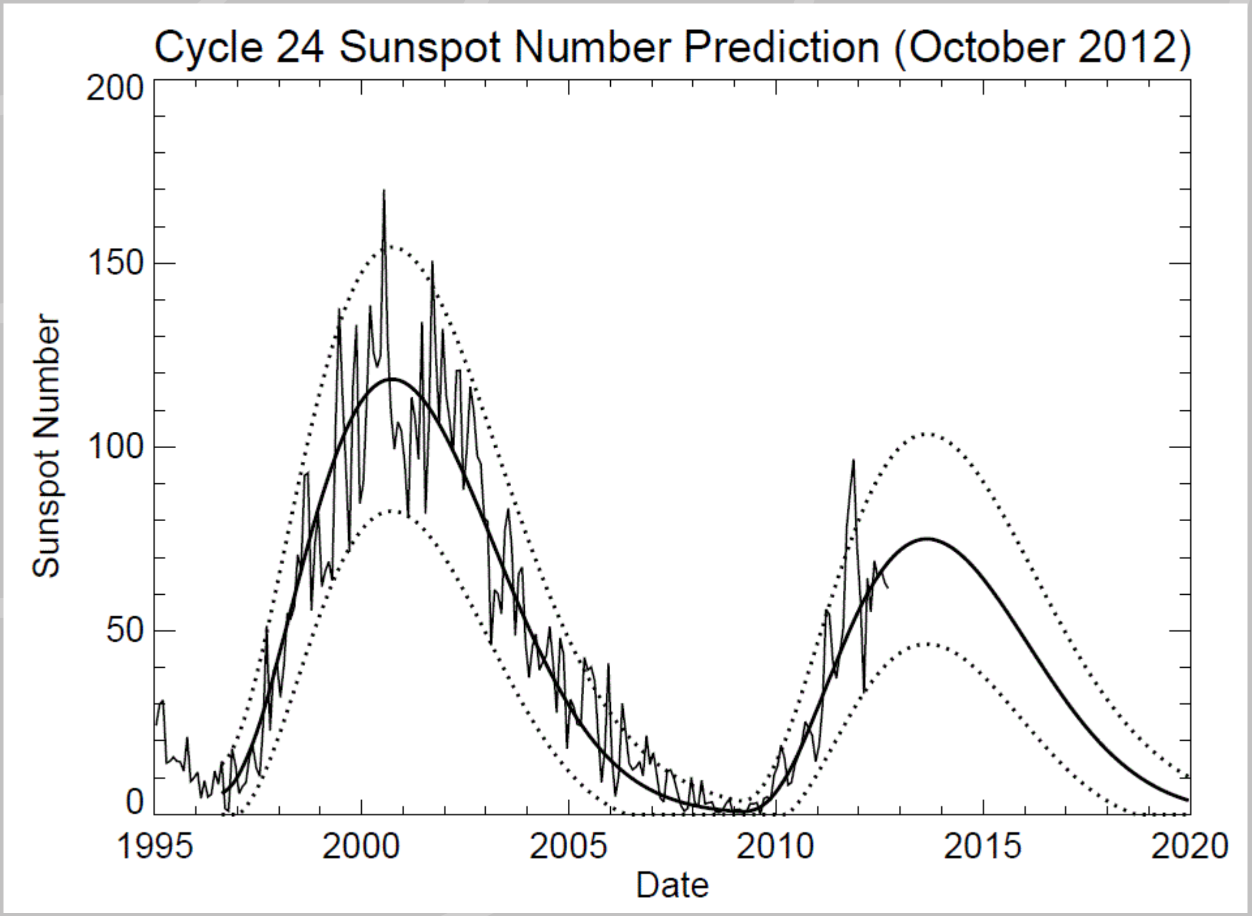
- *The most famous measure of the sun's activity; also popular in scientific contexts.*
- *Not quite accurate because it's based on visual observations, but there is a long tradition: the sunspots have been observed regularly since the 1600s.*
- *Defined in mid-1800s according to the way the sunspots were counted in the Zurich Observatory. Developed by the director of the observatory* ***Rudolf Wolf****.*
- *The relative sunspot number* ***R = k(10g + n),*** *where k is an observatory-specific constant, g is the number of sunspot groups and n is the number of individual spots.*

The variation in the sunspot numbers



There is a considerable random variation in monthly sunspot numbers. The average development of activity is better visualized by a smoothed sunspot number. During the sunspot maximum periods, there are typically two peaks.

The Cycle 24



Updated 2 Oct 2012:
A smoothed sunspot number maximum = 75 (Fall 2013).

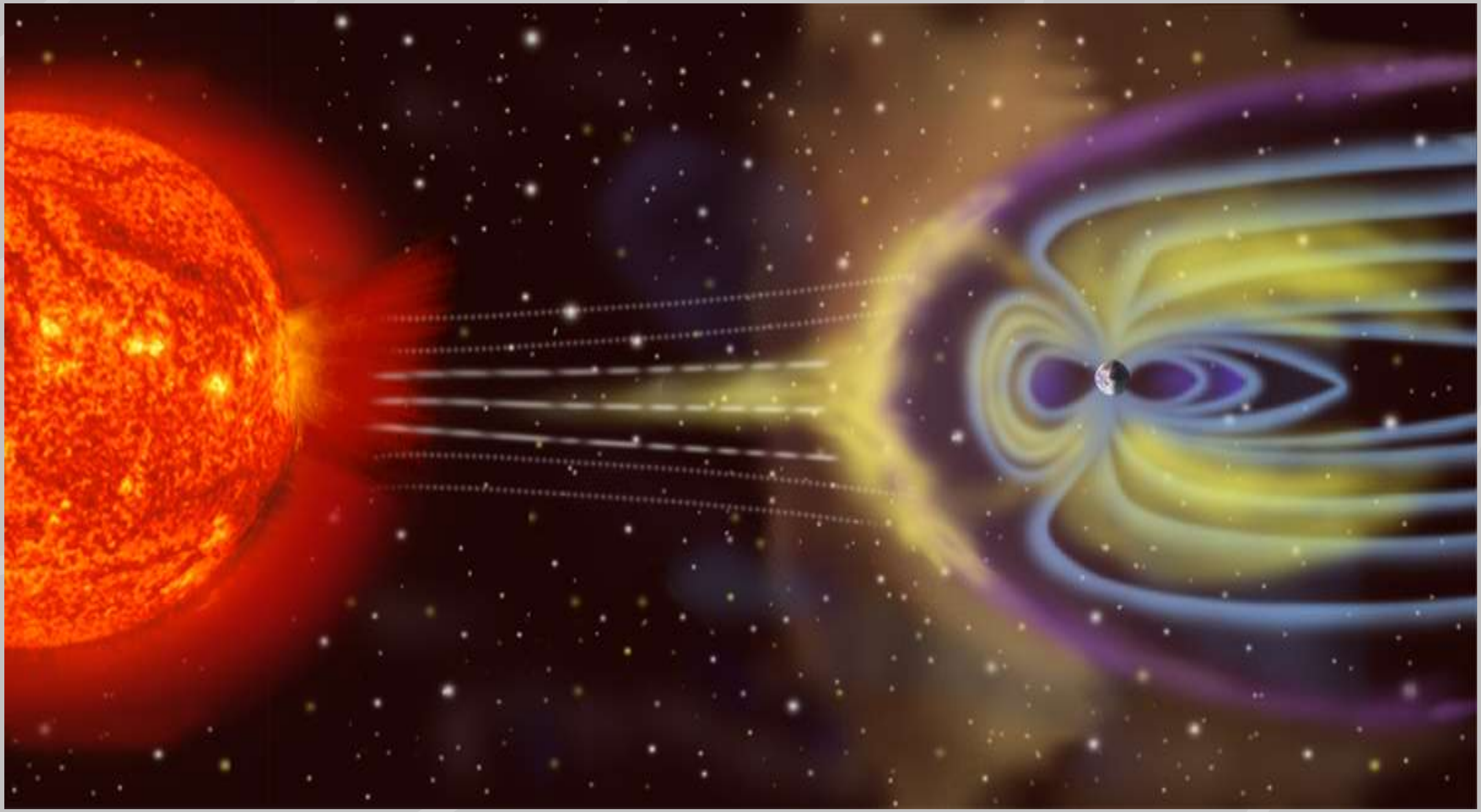
The smallest sunspot cycle since Cycle 14 which had a maximum of 64.2 in February of 1906.

http://solarscience.msfc.nasa.gov/predict.shtml

5. The solar wind

- *The solar wind originates from the **solar corona**, the outermost visible area in the sun. The corona is so hot that the atoms there cannot remain as atoms but they get ionized. That is why the solar wind is almost 100% ionized plasma, containing mainly protons and electrons.*
- *The ionized plasma conducts electricity very well. This means that the particles in the solar wind cannot travel against the sun's magnetic field lines but they travel along them. Therefore, the sun's magnetic field travels along the solar wind as if ”frozen” into it. This is how the interplanetary magnetic field, IMF, is born.*
- *The speed of the solar wind at the Earth's orbit is 400 km/s on the average, varying from 200 to 900 km/s.*

The solar wind



The sun’s magnetic field meets the Earth’s magnetic field.
Photo: Wikipedia

6. Irregular ionospheric variations

Most of the phenomena affecting the Earth's magnetic field and its disturbed conditions is related to variations in the structure of the sun's magnetic field. Usually, these phenomena deteriorate the radio wave propagation especially on higher latitudes. These events in the sun include:

- *Solar flares*
- *CME, coronal mass ejections*
- *Proton events*
- *Coronal holes*

On higher latitudes, electron densities are lower anyway, resulting in lower MUFs

→ use IonoProbe for (almost) real-time monitoring!

a) Solar flares

- ***The electromagnetic effect*** *can be felt already after 8 minutes, and it can cause a sudden ionospheric disturbance (SID) in the ionosphere (lasting appr. one hour or two).*
- *SID is usually more intense on lower latitudes (in the equatorial regions) and affects the entire HF range. The disturbance is felt on the daylight ionosphere in the form of increased D-layer ionization.*
- *The lower portion of the HF range is affected first. Higher frequency bands are the last affected, and they also recover first when the disturbance subsides.*
- ***The energetic particles*** *from the flare may arrive after 30 minutes at the fastest or maybe after 2 to 3 days.*

Solar flare classification

- The flares are classified by the intensity of x-ray radiation as follows:
    - A, B, C (weak)
    - M (moderate)
    - X (strong).
- An X-class flare is 10,000 times that of an A-class flare.
- C-class (and less) flares usually affect radio propagation only to some extent. As a contrast, M- and X-class flares may have a disastrous effect on HF radio propagation.

b) Coronal mass ejections, CME

- *A coronal mass ejection creates a **strongly magnetized plasma cloud** which travels into interplanetary space together with the solar wind.*
- *The CME is mucher bigger than a solar flare. Several billion (or tens of billions) tons of particles explode into space abruptly.*
- *At the fastest, a plasma cloud can travel from the sun to the Earth in one day, usually in 2-4 days.*

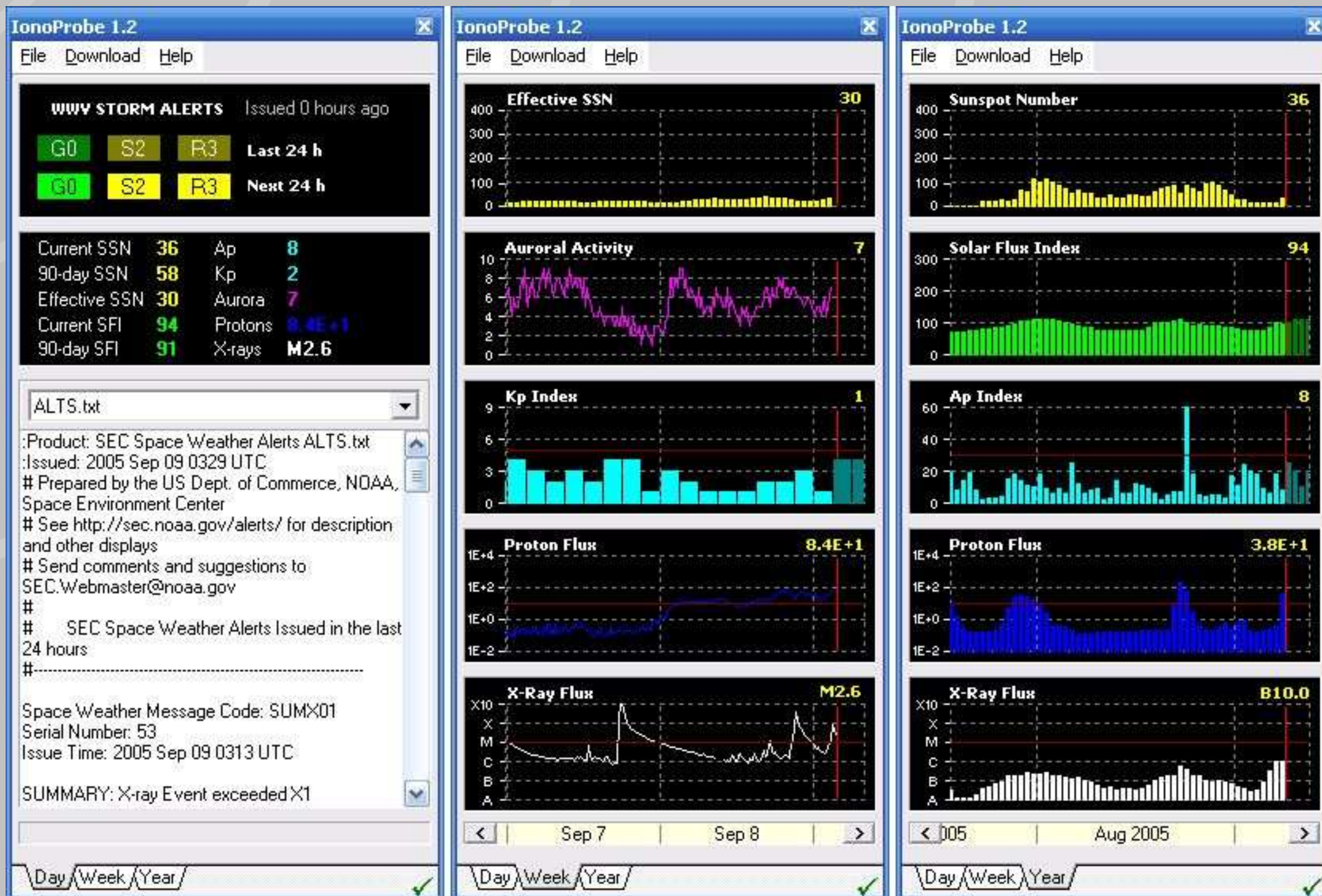
c) Proton events

- *In conjunction with a solar flare or a coronal mass ejection, a **high-energetic proton event** can also occur. It can reach the Earth's polar cap areas even in less than half an hour.*
- *A proton event effectively decreases radio signals that travel across the polar cap areas. This is called a polar cap absorption (PCA) event, or a polar blackout.*

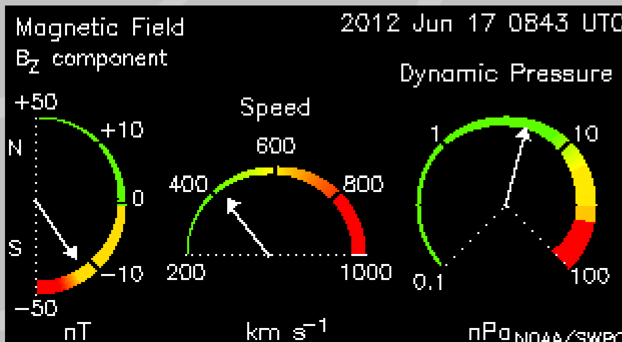
d) Coronal holes

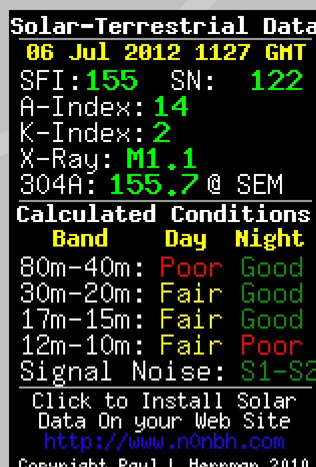
- *Coronal holes are a major source of disturbances, especially on the falling phase of a solar cycle.*
- *Coronal holes are* ***large magnetic regions where the magnetic field opens directly*** *into interplanetary space. As a result, the solar wind and particles unrestrictedly flow outward from the sun.*
- *In a suitable geo-effective position, coronal holes can produce disturbances that last several days even though there are no sunspots visible on the sun.*
- *Coronal holes live often longer than one solar rotation (at the sun's equator) i.e. 27 days. When the same hole comes into view after one solar rotation, the level of disturbance will once again increase. Some holes live even many solar rotations.*

7. Watching the space weather with IonoProbe



Watching the space weather online





Bz = strength and direction of the interplanetary magnetic field (minus values are bad)
Speed = speed of the solar wind (typically 400 km/s)
SFI = Solar Flux Index, intensity of solar radiation measured at 10.7 cm (2800 MHz) (62.5-300)
SN = sunspot number (0-250)
A-Index = daily average level of geomagnetic activity (0-400, storm trigger at 30)
K-Index = index calculated every 3 hours, measures disturbances in the magnetic field (0-9, disturbed at 5)
X-Ray = intensity of hard x-ray radiation (A0.0-X9.9, M-level means ”disturbed”)
304A = relative strength of the ultraviolet radiation at the wavelength of 304 angstroms i.e. 30.4 nm (0 ->). Loosely correlates to SFI and SN.

http://www.voacap.com/ssn.shtml
http://www.hamqsl.com

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More on the topic

- www.spaceweather.com
- sunearthday.gsfc.nasa.gov/spaceweather
- sidc.oma.be/products/meu/
- www.solen.info/solar
- Aurora forecast: helios.swpc.noaa.gov/ovation/
- contestclubfinland.com/pdf/CCF_Cruise_2012_K9LA.ppt

8. Using VOACAP on low bands

- Use VOACAP cautiously on longer paths on 160M and 80M, VOACAP will not predict DX confidently. OK maybe down to 40M (even there some issues).
- In the words of ON4UN: *”In my 40+ years of DXing on 80, and in my 15+ years on 160, I have never successfully used a propagation-prediction program.”*
- Use grayline maps instead, such as **GeoClock** or **DX Atlas**!

The low-band rules of ON4UN

For East-West paths:

- Peak at around sunset at the West end of the path
- Peak at around sunrise at the East end of the path
- Often a peak at local half-way midnight

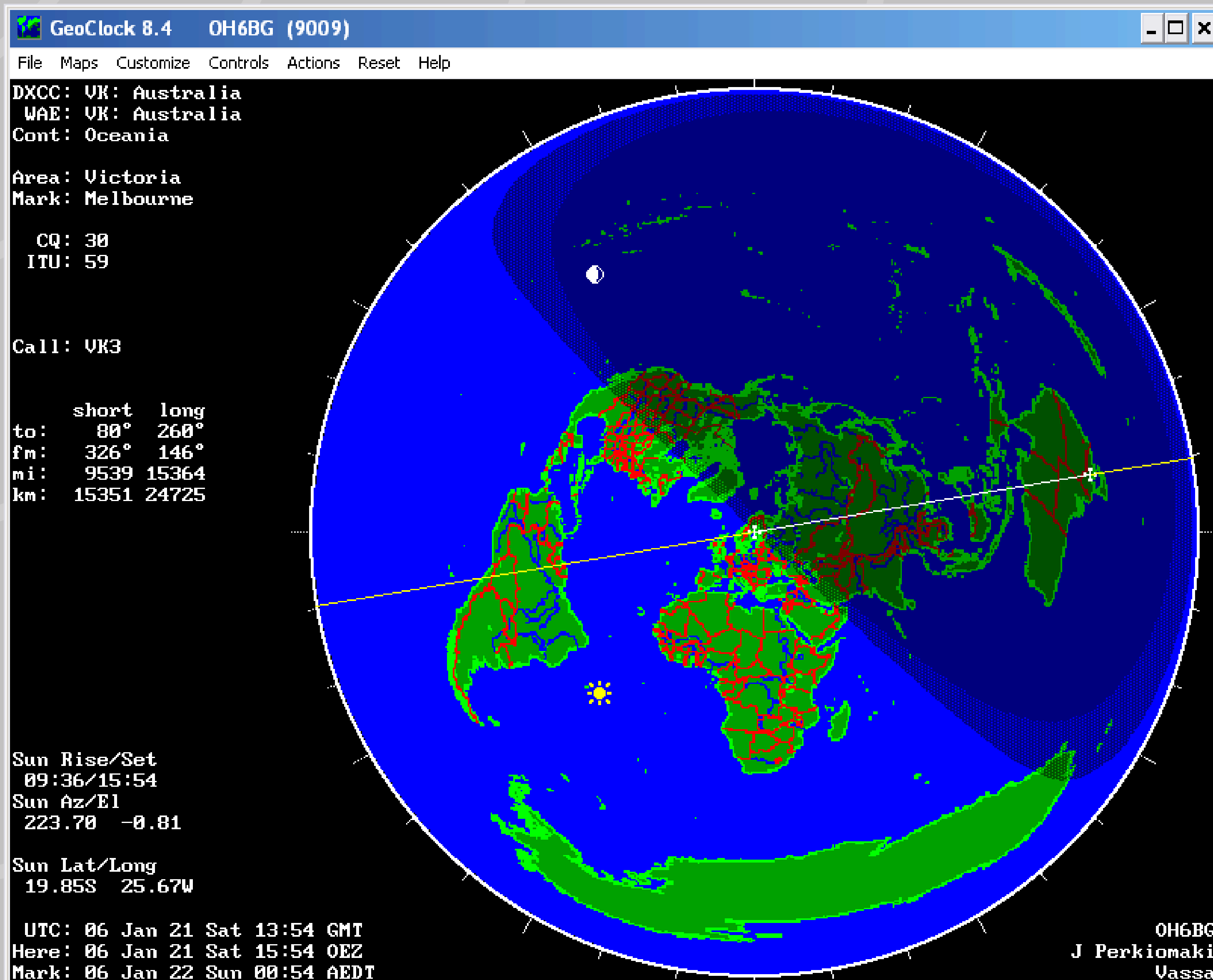
For North-South paths:

- Distinct peak at local midnight at the half-way spot

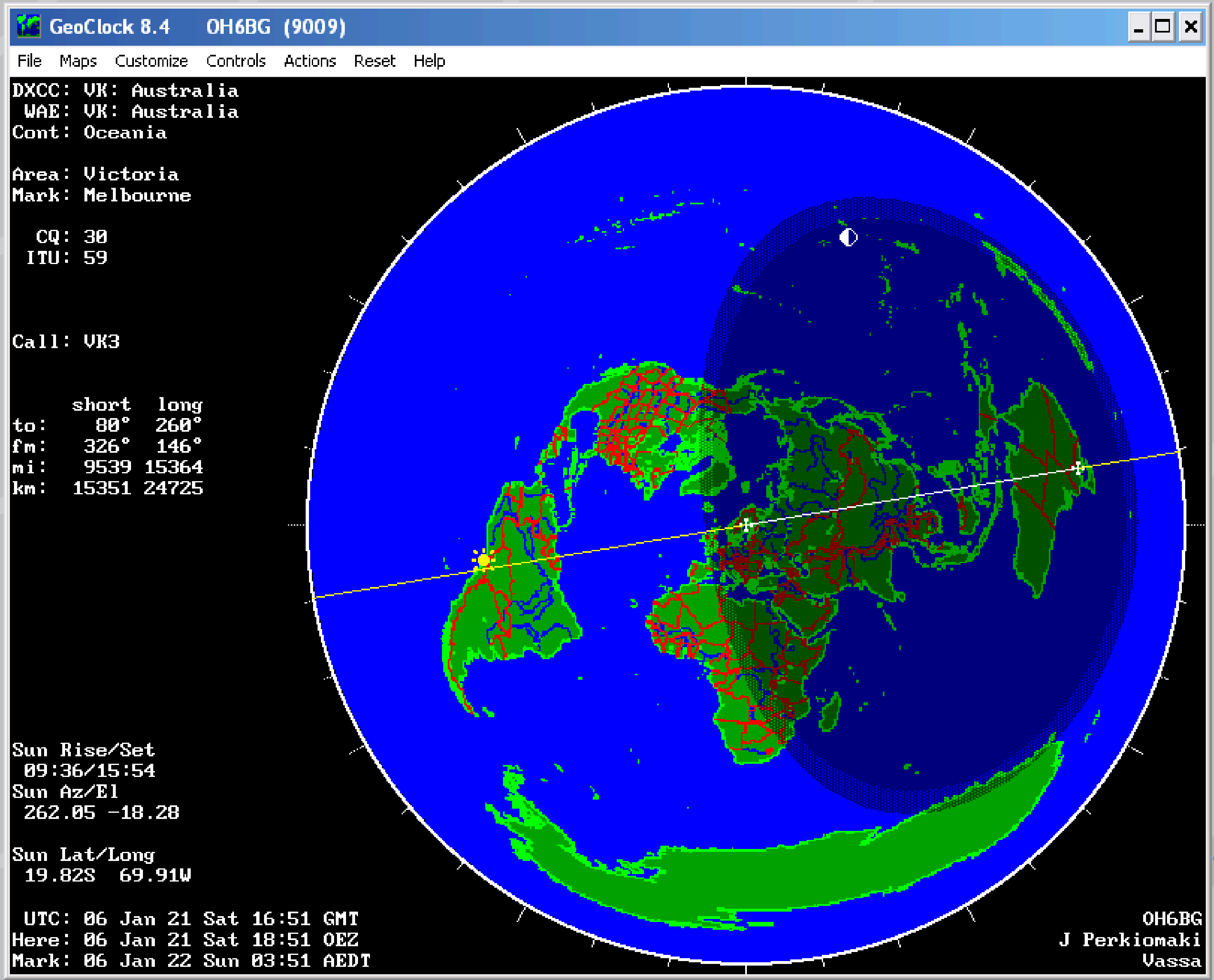
Half-way point calculator:

http://www.movable-type.co.uk/scripts/LatLong.html

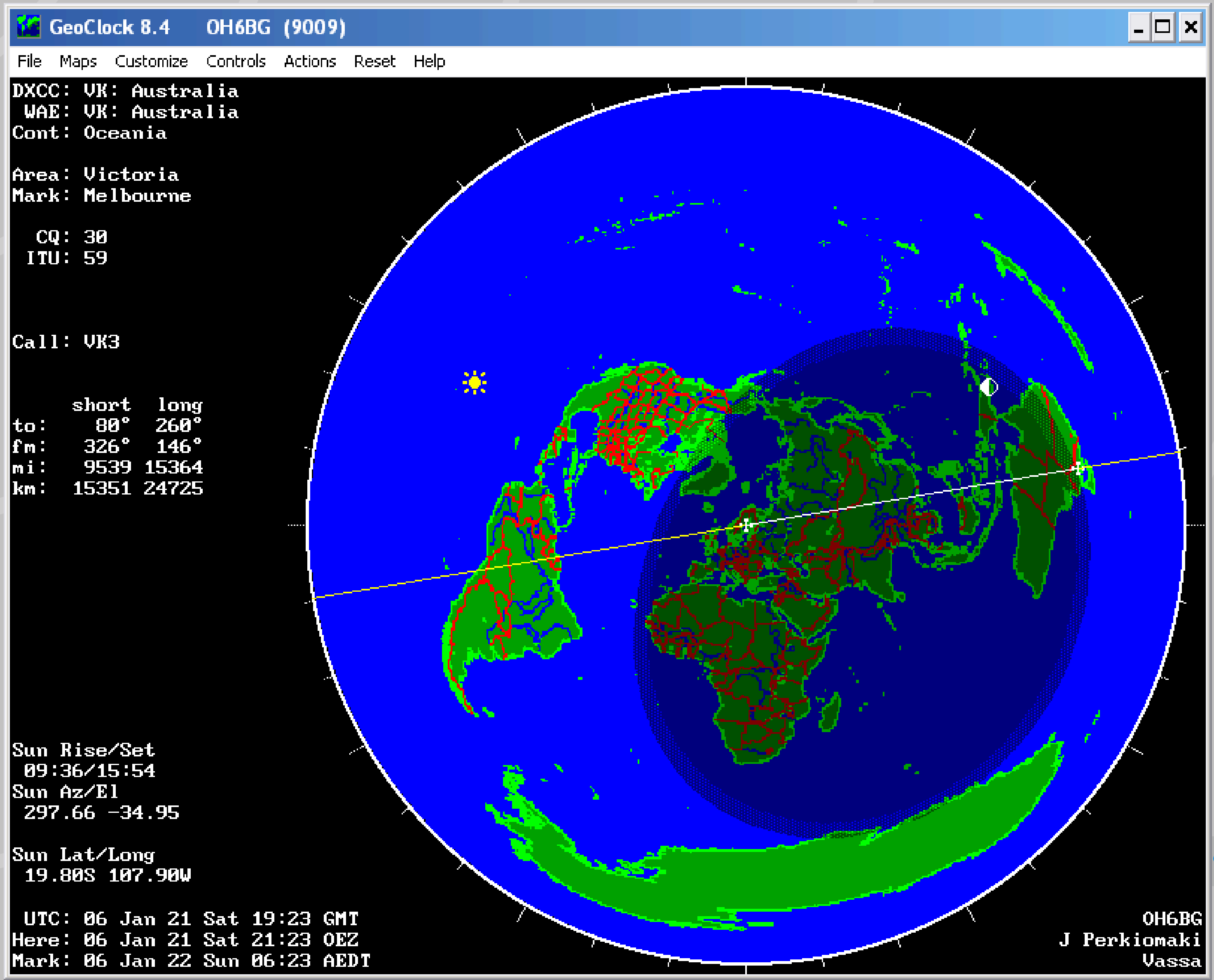
a) Sunset at West end of path (OH)



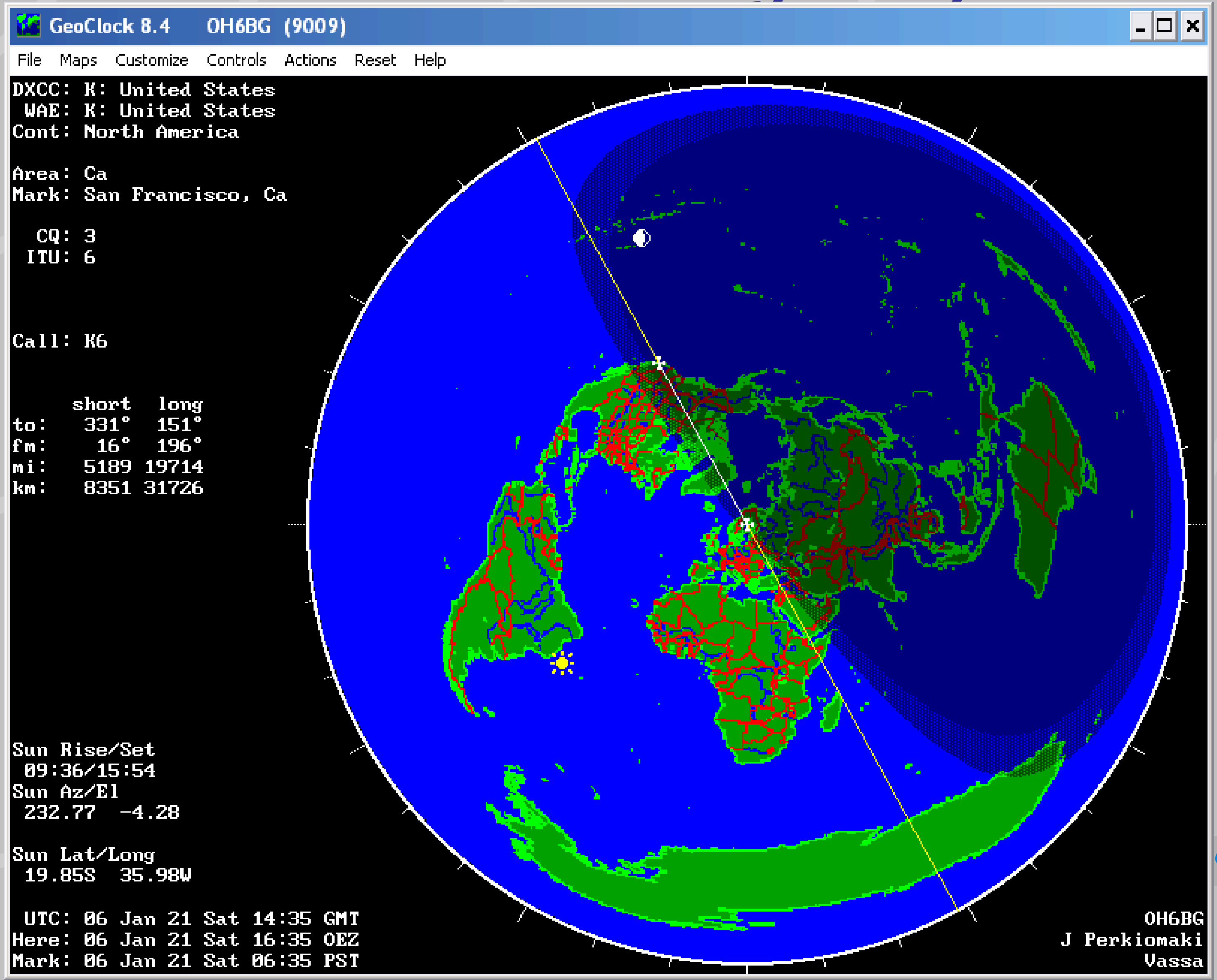
b) Midnight at half-way spot



c) Sunrise at East end of path (VK)



d) Skewed path (e.g. OH to W6, antenna beaming East)



9. Skimmers, real-time propagation monitoring

- *Simultaneous decoding of CW transmissions: one or more bands*
- *SDR (Software Defined Radio) and CW Skimmer /Skimmer Server (VE3NEA), max. bandwidth of 192 kHz per band*
- *OH6BG (KP03SD): QS1R SDR + Skimmer Server (7 bands simultaneously) + Mosley TA-53-M @15M AGL + 80/40M cross dipole*
- *Real-time feed of spots to Reverse Beacon Network and to* ***www.voacap.com/skimmer***

Reverse Beacon Network (RBN)

- ***www.reversebeacon.net***
- *Global, centralized publishing system for skimmer CQ spots*
- *The idea of RBN conceived in March 2008 by PY1NB and N4ZR*
- *Real-time propagation monitoring: look for band openings, test different power levels, different antennas, and beam headings*
- *Compare various spots graphically and download spot data for personal use*

10. Executive summary

- ***Theory in brief.*** *The sun's radiation creates the various layers of the ionosphere. HF signals reflect from the free electrons. The sun is the source of propagation disturbances.*
- ***Predictions.*** *The basic understanding comes from propagation-prediction software such as* ***VOACAP Online (online.voacap.com)*** *or* ***DroidProp****.*
- ***Grayline maps.*** *To understand propagation on lower bands, study grayline maps. Use* ***GeoClock*** *or* ***DX Atlas****.*
- ***Monitoring.*** *Use good tools for monitoring space weather and propagation in real time, e.g.* ***IonoProbe*** *and* ***RBN/skimmer****.*